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The Production Process of Manipulative for Commercial Purpose to Support the Success of Implementation of the School Mathematics Curriculum in Indonesia

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Abstract - The School Mathematics learning, particularly for the students of primary education (the nine years education), still needs the presence of manipulative. The manipulative is used to facilitate the need of the students and to develop their thinking ability. The problem raised is that the manipulative for mathematics learning is not available in the market, while the manipulative needs to be well-designed in order to be able to instill the mathematics concept and principle appropriately. Therefore, it is more appropriate that the development of manipulative should be done in the mathematics laboratory. In order to fulfill the demand of the market, however, there are several challenges, namely: the material quality of the manipulative produced in a laboratory is below the industrial product and the service to fulfill the market demand is below the standard. Those problems could be overcome by doing a multi-years research. The first year research aims to find the model of manipulative production process. The production process of manipulative includes: preparation, production process, and evaluation/validation. The production process was done through the participative collaboration synergy between the higher institution and the industry. This synergy is useful to support the implementation of school mathematics curriculum and to develop the partner industry in terms of product diversification and quality. By using this production model, it is supposed that we can produce manipulative for mathematics learning which is suitable with the characteristics of the students and the characteristics of the current curriculum. The result of the validation towards the products which was conducted by experts (academics, practitioner-teachers, and policy maker) gives good results. The finance analysis shows that the IRR is greater than the current interest rate and the value of PV proceeds is also greater than the PV outlays. Thus, we can conclude that the production process which is conducted through the synergy between the higher education institution and industry could produce the manipulative products which are valid and are appropriate to be commercialized.

Keywords: manipulative in mathematics learning, commercial, participative collaboration of higher institution and industry

INTRODUCTION

We started the first study about the availability of mathematics manipulative in elementary schools in Banjarnegara (Hidayah, 1991) and found that the availability and the the use of the manipulative were very low (33% - 38%). The availability of mathematics manipulative in Semarang was also low. It was only 40% - 52% average while the supply from the government only covered 5% and the average use in the mathematics learning was 49.5% (Sugiman, 1996). Furthermore, researches about the development of innovative mathematics learning by using manipulative and also its implementation to find out the effectiveness in terms of strategy and teaching aid innovation have been conducted (Hidayah, 1998, 2000, 2003, 2004, 2006, 2008, 2011, 2013).

Efforts to improve the quality of education have been implemented in various ways, such as improving the quality of educational components, including curriculum improvement. The quality improvement of mathematics learning is done through improvement of learning strategy or model and also the use of manipulative. The use of mathematics teaching aid (media/manipulative) is a must considering the mathematics material is abstract. The students of primary school age will be able to think when they are helped by concrete objects. The learning theories presented by Piaget, Bruner, and Ausuble suggest that learning will be meaningful if it is conducted in accordance with the mental state of students and presented with the pattern from the concrete stage toward the abstract stage. Bruner called it as a stage of enactive iconic-symbolic. The 2013 Curriculum, in the other hand, emphasizes the implementation of scientific approach which consists of several activities (observing, asking, trying, associating, and communicating). Study conducted by Ghazali (2010) on the effective learning of number found that the teachers emphasize efforts to present problems which are easy to be understood by children. The teachers used the following steps: modeling, using concrete objects (manipulative, the representation of the image-visual media, and ending with a mathematical abstraction). The teacher was able to encourage a high level of participation for students through these activities.

The effectiveness of problem based mathematics learning with the use of media (teaching aids) has been tested in elementary school, junior high school, senior high school, and higher education (Hidayah, 2003). Th

testing results of mathematics learning by using manipulative in elementary schools in six provinces (North Sumatra, Central Java, East Kalimantan, North Sulawesi, South Sulawesi, and West Nusa Tenggara) showed that the mathematics learning by using manipulative could improve the learning quality and overcome the limited ability of teachers to master of concepts/principles of mathematics, as well as to prevent the misconceptions (Hidayah, 2004). Research on mathematics learning in elementary school by optimizing the use of environment and manipulative as the learning resources (Hidayah 2008; Pramasdyahsari, 2010) found that the learning is fun, is able to develop the exploration ability well with the rate of exploration activity was 86.75% and the average result of exploration test was 73.57. The identification results of manipulative needed for learning concepts and principels of mathematics in primary and secondary education suggest that there are 51 kinds of manipulative (Sugiarto, 2010). Hidayah (2013) conducted a research of mapping the mathematics basic competence in the thematic learning mathematics and found that the manipulative manufactured by the Mathematics Laboratory of Semarang State University still need necessary adjustments to be suitable with the the themes and subthemes of thematic learning.

The results of various researches above show that the existence and the utilization of manipulative is important to optimize the implementation of the 2013 Curiculum. Besides, the Regulation of the Ministry of National Education (MoNE) No. 16/2007 suggests that teachers should possess pedagogical competence in a form of being able to use relevant learning media and sources which are suitable with the students' characteristics and the subject characteristics in order to achieve the learning goal. The Regulation of the Ministry of Education and Culture (MoEC) No. 65/2013 also demands teachers to use various learning approaches, media, and sources. The Appendix IV of Regulation of MoEC No. 81A/2013 also states that the use of media, tool, and source of learning should be written in the lesson plan. These regulations confirm that the use of the learning media is important within the learning in elementary and high school.

The importance of the use of mathematics learning media has been recognized and understood by schools and teachers, however, the media are not yet available on the national market. Some types of mathematics manipulatives like solid shapes are available on the market but they are not suitable with the characteristics of mathematics learning nor the characteristics of the curriculum, thus, they are not applicable. While the manipulatives which have already met the criteria will not be effective either if the teachers can not use it properly within the learning. In the other words, the manipulatives could not facilitate students to do mathematics abstraction. The mathematics leaning media should be developed in accordance with the students' characteristics, the mathematics learning characteristics, and the curriculum characteristics. They shoud also be equipped by instructions to use them within the learning.

Some schools (elementary school, junior high school, and senior high school) and universities have used the manipulative products from Semarang State University as shown by the number of selling product of manipulative in 2010 is 29 isntitutions (2 elementary schools, 1 Islamic elementary school, 22 junior high schools, 3 Islamic junior high schools, and 1 higher education) in Central Java, Yogyakarta, and West Sumatra (Sugiarto, 2013). The manipulative products in the mathematics laboratory still have limitations such as the quality of the product, the readiness of the product stock, and the fulfillment of order which can reach 1 month.

CV Children Toys is an industry built in 2007. It provides educative teaching aids with some advantages, namely: (1) the product is suitable with the competence standard of early childhood/kindergarten education, (2) there are various product available, (3) tested in producing teaching aid, (4) provide products for retail, small party, and grocery, (5) the product is used by almost all early childhood/kindergarten education all over Indonesia, and (6) the service is fast, proper, and suitable.

Based on the facts above, it is necessary to develop and to market the mathematics learning media (manipulative) for elementary and junior high school in synergy between Semarang State University and the Children Toys industry as the partner. By this synergy, the product is supposed to be used by the consument appropriately and correctly. As the initial stage, this research aims to find the model of manipulative production process and to do the financial analysis (business plan) to find out the appropriateness of the manipulative production as a commercial business.

METHOD

This research used Research and Development design (Gall *et al.*, 2003) which was conducted in collaborative-participative way between team of Semarang State University and the Children Toys industry. It aims to optimize the management of the research implementation including the stages of design planning, implementation (production process), reflection, and process and product innovation.

The stages of the research in detail include: (1) Construction of the manipulative design in mathematics learning has been adapted to the 2006 and 2013 curriculum, along with the specifications of shape, size, color, material, and supporting tools required. The design of manipulative is equipped with the prototype made by the mathematics laboratory team of researchers to facilitate the industry to adjust the production. This activity is carried out in the laboratory of mathematics by involving students. (2) The design of manipulative and the sample products is then delivered to industrial partners, along with the required arguments (manipulative requirements for mathematics learning in primary and

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junior high school) to obtain a mutually agreed manipulative design. (3) Preparing and completing the tools and materials prior to the production stage. Training and assistance for production staffs is important for new products with the next new method as well as providing the principles of making manipulative and how to use it. This is done to minimize product errors. (4) The production activities are carried out in the industrial partner, while the usage instructions is made by the research team. (5) Evaluation of the product is needed to determine the possible revision or repair of the product. (6) Validation test by experts (academics, practitioners, and policy makers). (7) Analysis of the results of validation. (8) Determination of manipulative production process for school mathematics learning. (9) The preparation of the pilot plan and business plan.

Results and Discussion

Construction of manipulative design refers to the mapping of the 2006 Curriculum and 2013 Curriculum as the current curriculum implemented at schools are the 2006 and 2013 curriculum. Based on the materials of school mathematics, the results of the mapping and development of manipulative design is classified into 4 groups of manipulative, namely: the planar shape manipulative (Gd), solid shape manipulative (Gr), algebra manipulative (Alj), and arithmetic manipulative (Art). While based on the raw materials used for the production, the products are classified into 3 groups: the manipulative with the raw material of wood or MDF, the manipulative with evaform raw materials, and the manipulative with plastic raw materials. As a reference of production, in addition to the design of manipulative, researcher also made a code book of manipulative teaching aids for primary education mathematics in the material of planar shape, solid shape, algebra, and arithmetic.

The result of transferring design and requirement of manipulative in mathematics learning has generated innovation and creativity of researchers and industrial partners in terms of the specification of the product, especially the product of wood or MDF. The innovation and creativity could ease the use of manipulative in learning. The innovation of manipulative of volume and surface area of the cylinder, cone, and sphere lies in the raw materials used.

The tool and material for the production of solid shape manipulative have been available at the industry partner, while the production of solid shape manipulative needs a particular cutter. We have prepared 26 types of cutter for production of 12 kinds of planar shape products. We have also prepared blowing and moulding machine for production of cylinder, cone, and sphere model. The blowing and moulding machine could produce 7 kinds of manipulatives.

The process od manipulative production is carried out on an industrial partner, with accompaniment by the owner of the industry and the research team. Thus, during the production process, we also conduct evaluation, feedback, and follow-up. Innovation occurs during the production process. Based on the research design in the research stages, the production process is evaluated at each stage and some repairs or improvements related to component design, workmanship, materials, as well as complementary products have been done. Innovations on each type of manipulative are not always the same.

The production process of manipulative with MDF material requires stages as follows: making pattern, cutting sheets of MDF material into smaller pieces, cutting to the pattern, refining by using refinemen machine, constructing by using glue and small nails closing the pores, sanding, installing magnets, painting finishing, and then packaging. For wooden material before poceeding to the same steps, the material should b cut such that the wood has a plane form. The productio process of manipulative with evaform material follow the stages: cutting evaform into pieces of smaller size cutting with a cutter machine, assembling, finishing, an packaging. While industry partners do not yet have cutter machine and this research could not provide thes machines because of limited funding, thus we ask fc assistance of another indistrial partner. While th production process of manipulative made from plasti need blowing and molding machine that has bee prepared. It can be done with quite simple stages, wit cycle time of around 1 minute or we can produce 60 p in 1 hour.

Validation of experts towards the products that hav been produced by industry partners carried out t academics, policy makers (principals and scho supervisors) and practitioners (teachers) of mathemati in primary and secondary education. The validat components include: the manipulative requiremer including security aspect for students, usefulness, a ease of use. The products of manipulative have be equipped with a guide book on how to use t maniputaive in mathematics learning. The book constructed referring to the mapping of competences the 2006 and 2013 curriculum. The results of t validation obtained an average score of .4.8 out of maximum score of 5. In addition, the analysis shows t there was no significant difference result among t academics, policy makers, and practitioners. Howev there are inputs for the improvement of manipulat related to safety of students, namely towards the plas cone manipulative product. The apex of the cone v considered not safe for primary education students. order to overcome this, there are two alternatives, the f alternative is to replace the base material with evafc material and the second alternative is by putting sa component at the apex of the cone. The manipulative mathematics learning generated in this research are manipulative that have been developed through a serie research activities, application at school by practitio (teachers) and the researcher, and education/learr through Mathematics Learning Media lectures. development of manipulative is done to achieve the

of learning mathematics (active learning, innovative, creative, effective, and fun), as well as efficient. The use of manipulative, will help teachers and students so that learning is not a waste of time, because of limited learning facilities. Innovations made for manipulative products is innovation in terms of effectiveness of learning, it means that by using manipulative, the concepts / principles of mathematics are easier to be accepted / understood by the students. Thus the manipulative helps mathematics becomes meaningful for students. The products are supported with innovation, raw material innovation, innovation forms (attractive, easy to use, easy to store, easy to carry), packaging innovations. In cooperation with CV. Children Toys who have had experience of 7 years of operation with manipulative educational products, with some advantages, we will be able to perfect the products of manipulative at Semarang State University. In addition, the advantage of products is that they are equipped with instructions to use in learning. Instructions for use are provided not only clue as cooking instructions (recipe book), but instructions which contain a series of productive questions, requires students to answer or make a series of activities to discover concepts / principles of mathematics. Thus, the use of manipulative products from this study give consequences of constructivist learning, involving activities of observing, asking, trying, reasoning, and communicating as demanded by the 2013 Curriculum and 2006 Curriculum, with emphasis on exploration activities, elaboration and confirmation.

Referring to the preparation and implementation of the production process of planar shape, solid shape, algebra and arithmetic manipulative with the material of wood/MDF, evaform, and plastic, we have formulized production model of manipulative as shown in the Figure 1.

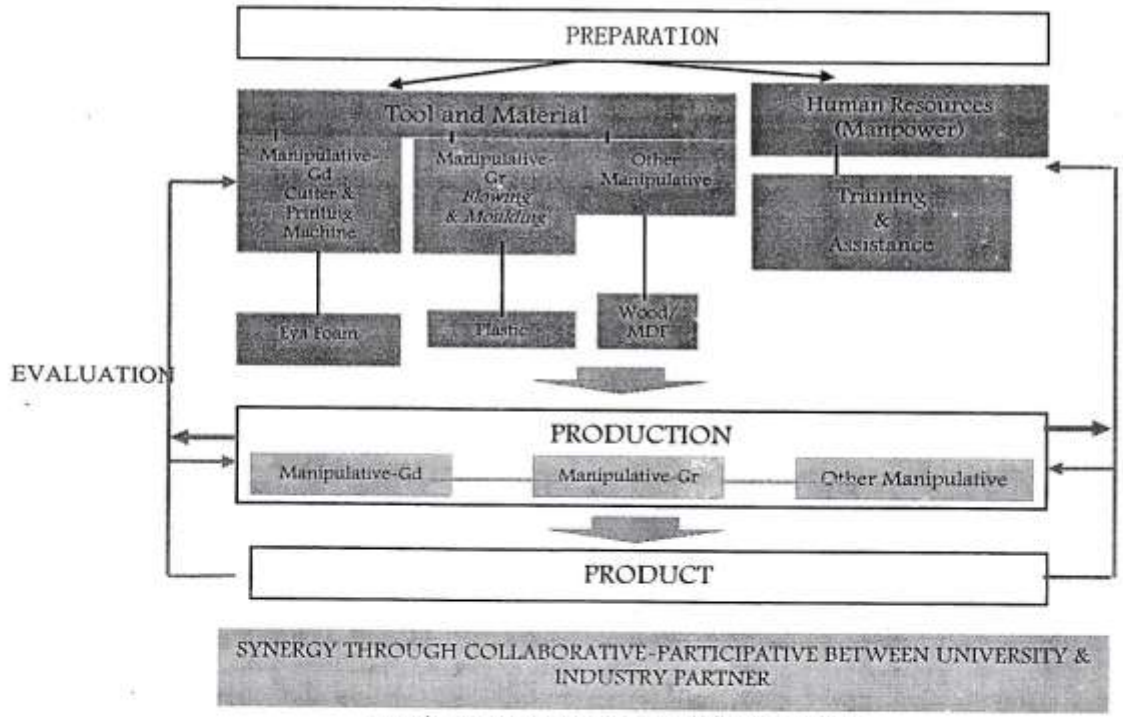

FIGURE 1. MODEL OF MANIPULATIVE PRODUCTION PROCESS

For commercial purpose, we have conducted analysis in various aspects such as production analysis, marketing analysis, socio-economics analysis, and financial analyisis. In the socio-economics aspect, the availability of manipulative in mathematics learning could overcome the teacher's difficulty to implement meaningful and fun mathematics learning. Teacher could also train the students to possess critical and creative thinking ability as well as problem solving ability. By using manipulative, teacher is expected to be able to facilitate students to do the following activities: observing, asking, trying, associating, and communicating as the basis of critical and creative thinking and problem solving. These manipulatives are important for every mathematics learning at primary and secondary school. In the finance aspect, we have conducted an analysis to determine the fixed cost, variable cost, production cost, basic price, break event point, financial report assumption, and

investment appropriateness. The analysis of the product basic price, we got information that the selling price of solid shape and algebra manipulative (wooden/MDF material) is IDR 3,100,000/package; the selling price of cylinder, cone, and sphere manipulative (plastic material) is IDR 250,000/package; and the selling price of planar shape manipulative is IDR 2,850,000/package. The break event point for 1 year sale is 9 packages of solid shape manipulative, 58 packages of cylinder, cone, and sphere manipulative, and 1 package of planar shape manipulative. The analysis of investment appropriateness give information that the payback period is 11 months 24 days. The internal rate of return is more than the bank interest rate (66% > 6%). Thus, the business of manipulative is appropriate to be funded through bank credit. The value of PV proceeds is more than the PV outlays and it confirms that the investment is appropriate. Finally, we can say that the business of manipulative production for mathematics learning can be run for commercial purpose.

CONCLUSION

The conclusions of this research are: (1) the manipulative products manufactured by the industry partner are planar shape manipulative, solid shape manipulative, algebra manipulative, and arithmetic manipulative which can be classified into 3 groups based on the production material, namely wood/MDF, evafoam, and plastic. (2) The model of manipulative production process includes: preparation stage, production stage, and evaluation stage. The evaluation stage also gives feedback and follow up at every stage of production to enable the emerge of innovation in terms of material, tool, production process, as well as finishing. The production process is conducted in collaborative-participative way between university and industry partner. (3) The manipulative products manufactured by the industry partner have fulfilled the validity and requirements as the mathematics teaching aid for primary and seconday education. They also fulfilled the criteria of usefulness and easy to use for the learning implementation. Thus the availability of manipulative could support the implementation of the current curriculum. (4) The mathematics learning manipulative production can be a commercial product business run by industry partner.

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